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technical note

EVALUATION OF ALUMINIZED STEEL MUFFLERS AND TAILPIPES

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INTRODUCTION

The Evaluation of Aluminized Steel Mufflers and Tailpipes, Project NY 512 023-1, is an outgrowth of Project YD 513-1 which covered the investigation of ceramic coatings for mufflers and tailpipes. As reported in NAVCERELAB letter NT4-59/YD 513-1 791/JRD/mg Serial 1023 dtd 25 July 1952 to BUDOCKS, it was found that ceramic coatings were not economical for automotive type exhausts. Aluminized steel was suggested as an alternate material. The investigation of aluminized mufflers and tailpipes was initiated by YDSO letter NM24-5(1)/J6 3564/ms Serial 16966 dtd 20 Aug 1952 to NAVCERELAB.

Aluminized steel is made commercially by dipping sheet steel in molten aluminum under a salt flux. The process, known as Aldip, was developed at the General Motors Research Laboratories.

For the purpose of identifying materials in this report, the term "aluminized" is used to refer to aluminized steel and the term "steel" to refer to plain steel.

OBJECTIVE

The objectives of this project were:

1. To establish the relative corrosion resistance of aluminized and steel mufflers and tailpipes by comparative tests; and

2. To compare the annual cost of aluminized and steel replacement mufflers and tailpipes for a typical Navy vehicle.

To carry out the objectives of the project, a number of mufflers and tailpipes of aluminized and steel construction were installed on vehicles and stationary gasoline engines. The relative corrosion resistance of each part was established by measuring its loss of weight or by noting its service life. The life expectancy of each part was deduced from the test data and from the repair-parts histories of 30 Navy vehicles. Finally, the annual cost of aluminized or steel replacement parts was determined for a Chevrolet sedan from the established life expectancies and from parts and labor costs.

DESCRIPTION OF MUFFLERS AND TAILPIPES

Item	Material	Type
Muffler A	aluminized	Plymouth '36-'41
Muffler B	steel	Plymouth '36-'41
Muffler C	aluminized	Chevrolet '49-'52
Muffler D	steel	Chevrolet '49-'52
Tailpipe A	aluminized	Chevrolet '49 Sedan
Tailpipe B	steel	Chevrolet '51 Pickup Truck

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The mufflers and tailpipes listed above were not company stock items, but were high quality parts manufactured for replacement on the vehicles indicated.

The aluminized mufflers had an aluminum coating on both sides of their shells, while mufflers C and D had their shells lined on the interior with a light gauge steel sheet that was not aluminized. The inner tubing and end plates on all four mufflers were fabricated of plain steel. This was done in the case of the aluminized mufflers because the forming process would have damaged the aluminum coating. The aluminized tailpipe was coated with aluminum both inside and out.

TEST PROCEDURE

Mufflers

The mufflers were weighed and installed on several stationary gasoline engines and automotive vehicles. Mufflers A and B were installed on Chrysler industrial gasoline engines as shown in Figure 1. The engines were operated at constant speed for a total of 746 hours as follows:

1. One hour each day for 360 work days, alternately running for 1/2 hour and shut down for 3 hours. (A work day is defined as any day in the work week, Monday through Friday.)

2. Four hours each day for 37 work days, alternately running for 2 hours and shut down for 2 hours.

3. Seven hours continuously each work day for 34 days.

The operating schedule was governed in part by other tests which were running simultaneously with the muffler test.

Mufflers C and D were installed respectively on a 1951 Chevrolet pick-up truck and on a 1949 Chevrolet sedan. The vehicles were used for routine services at the Construction Battalion Center, Port Hueneme, California, and were operated under light loads on short runs.

At the conclusion of testing, each muffler was pickled in a 100% solution of Oakite #131 to remove all material except the solid metal. The mufflers were then reweighed. The net loss of weight was attributed to corrosion.

Tailpipes

Tailpipe A was installed simultaneously and in conjunction with muffler D on the 1949 Chevrolet sedan, and tailpipe B with muffler C on the 1951 Chevrolet pickup truck. For tailpipe evaluation, records were kept on tailpipe life and vehicle mileage.

TEST RESULTS

Mufflers

1. Chrysler industrial engines: Steel muffler B lost 2.65 times as much metal due to corrosion as aluminized muffler A over the same operating period.

2. Vehicles: Steel muffler D lost 3.35 times as much metal due to corrosion as aluminized muffler C on an annual basis. This figure should be corrected to 1.70, however, because the steel muffler was subjected to more severe service than the aluminized muffler.

Tailpipes

1. Although aluminized tailpipe A was subjected to more severe service than steel tailpipe B, it had a 17% longer life. When compared to average steel tailpipe life on sedans, however, the aluminized tailpipe had a 25% longer life. The latter comparison is considered to be the more appropriate.

DISCUSSION OF TEST RESULTS

The test results are based on data tabulated in Appendix 1.

Correction of the vehicle muffler test results was found to be necessary from a survey of the repair histories of 30 Navy vehicles operated at the Construction Battalion Center, Port Hueneme. The survey (see Appendix 2) showed that steel mufflers had a 1.97 longer life on Chevrolet pickups than on Chevrolet sedans. In order that the final test results should take into consideration the relative severity of test conditions, the initial result of 3.35 was divided by 1.97 to obtain 1.70, the corrected result. The correction was based on the assumption that the weight loss due to corrosion varies inversely as muffler life expectancy. This assumption is considered to be conservative since muffler corrosion probably decreases with time. In similar types of corrosion the accrued scale acts as a shield and decreases the rate of further corrosion.

The distribution and effect of corrosion on aluminized and steel exhaust systems were clearly shown by these tests. External corrosion was practically nonexistent on the aluminized components, and, except for some minor rust incrustation on the tip of the tailpipe, little damage was done to the exterior aluminum coating. External corrosion on the steel components was very heavy, however, and it was evident that this corrosion contributed significantly to the short life of these components (see Figures 2, 3, 8 and 9).

Internal corrosion was substantial in both systems. No trace of the internal aluminum coating remained on the aluminized mufflers or tailpipe. From Figures 4, 5, 6 and 7 it can be seen that internal corrosion was heavier in the steel mufflers than in the aluminized mufflers. The effect of the internal aluminum coating in retarding corrosion was not proved in the tests of mufflers C and D since, as was explained in the section describing the muf-

flers, the interior lining of these mufflers were made of plain sheet steel. The greater corrosion in muffler D corroborates the previous finding that the exhaust systems on the sedans were subjected to more adverse service than those on the pickups.

Internal corrosion caused metal losses to occur uniformly throughout the muffler and tailpipe assemblies except for the last few feet in each tailpipe. Here, the corrosion was considerably greater, and holes formed chiefly along the bottom. These holes developed from the inside as can be seen in Figures 9 and 10.

Condensation of exhaust gases probably was the major cause of internal corrosion since the condensed moisture was highly acidic. Condensate samples taken from various vehicles ranged in pH from 2 to 4. Condensate with pH values in this vicinity are corrosive to steel.[1] The moisture apparently condensed on the interior surfaces of the exhaust system during warm-up periods when the surfaces were below the dew point temperature of the gases. The condensate was adsorbed by the carbon deposits. According to available literature[2] the dew point temperature of exhaust gases is in the vicinity of 150 F.

The heavy internal corrosion in the last few feet of the tailpipes presumably was caused by the fact that this section operated at temperatures below the dew point of the exhaust gases for longer periods and accumulated more condensate.

RESULTS OF COST COMPARISON

Use of aluminized mufflers and tailpipes as replacement parts in lieu of steel parts will result in annual cost savings of 37% in the case of mufflers and 14.5% in the case of tailpipes. These savings apply to 1949 through 1952 Chevrolet sedans operated by the Navy in the Port Hueneme area. Substantiating data for these results are summarized in Appendices 3, 4 and 5.

GENERAL DISCUSSION

Cost comparison shows that use of aluminized mufflers and tailpipes on 1949 through 1952 Chevrolet sedans at Port Hueneme should result in appreciable savings. It is recommended, therefore, that present exhaust-parts-stocking procedures for these vehicles as established by the BUDOCKS Repair Parts Catalog be amended at Naval establishments in the Port Hueneme area. Aluminized mufflers and tailpipes should be carried as stock items rather than as superseded items. If this change is adopted, parts life and cost records should be maintained so that proper analyses can be made. Future

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1. Uhlig, H. H., The Corrosion Handbook, John Wiley & Sons, Inc., 1948, p. 129.

2. Georgi, C. W., Motor Oils and Engine Lubrication, Reinhold Publishing Co., New York, 1950, p. 371.

procurement costs should be checked against the records to see that aluminized parts do not cost more than steel beyond certain limits. For example, according to present calculations, aluminized mufflers could cost 2.18 and aluminized tailpipes 1.51 times the present cost of steel parts before a loss would result.

In view of the superior corrosion resistance and economy which was shown by the aluminized mufflers and tailpipes in this investigation, additional tests are recommended. Aluminized and steel exhaust systems should be in-service tested on various vehicles under different climatic conditions. Tests should be conducted on jeeps, sedans, and trucks in tropical and cold climates to determine the effects of humidity and temperatures on the life of aluminized and steel parts. Each test should consist of at least three identical sub-tests so that an average parts life may be obtained. For simplification and economy, only aluminized parts that are readily available from the commercial market or from BUDOCKS repair stocks should be used. Each test should continue until the test muffler or tailpipe fails. Failure of a part may be determined by visual inspection, and may be defined as that stage of corrosive decay where one or more holes totalling approximately one square inch in area have developed in the shell of the part. Finally, an economic analysis should be made for each type of operation tested.

CONCLUSIONS

1. The aluminized mufflers and tailpipe were superior to the steel in corrosion resistance.

2. The use of aluminized mufflers and tailpipes as replacement parts will result in reduced maintenance costs on 1949 through 1952 Chevrolet sedans at Naval establishments in the Port Hueneme area.

RECOMMENDATIONS

1. It is recommended that aluminized mufflers and tailpipes be used as replacement parts in lieu of steel on 1949 through 1952 Chevrolet sedans at Naval establishments in the Port Hueneme area. Records of parts life and costs should be preserved as a check on the economy of future procurement.

2. It is recommended that comparative in-service tests be conducted on aluminized and steel exhaust systems on various vehicles and equipment under different climatic conditions to further evaluate such systems.

APPENDIX 1. TEST DATA

	Installation	Original Weight (lb)	Pickled Weight (lb)	Net Weight Loss (lb)	Operating Period	Operating Mileage	Annual Weight Loss (lb/yr)	Weight Loss Per Mile (lb/mi)
Muffler A (aluminized)	Chrysler engine	7.035	6.116	0.919	746 hr	-	-	-
Muffler B (steel)	Chrysler engine	6.531	4.104	2.427	746 hr	-	-	-
Muffler C (aluminized)	Chevrolet pickup	9.018	8.650	0.368	2.02 yr	21,371	0.182	1.72×10^{-5}
Muffler D (steel)	Chevrolet sedan	9.226	8.035	1.191	1.96 yr	23,664	0.609	5.04×10^{-5}
Tailpipe A (aluminized)	Chevrolet sedan	-	-	-	1.10 yr	7,580	-	-
Tailpipe B (steel)	Chevrolet pickup	-	-	-	0.937 yr	9,827	-	-

APPENDIX 2.
RESULTS OF SURVEY OF 30 VEHICLES OPERATED AT CONSTRUCTION BATTALION CENTER, PORT HUENEME, CALIFORNIA

	Average Miles Per Year	Steel Muffler Average Life	Steel Tailpipe Average Life
15 Chevrolet sedans	15,400	1.27 yr	0.880 yr
15 Chevrolet pickups	11,500	2.50 yr	1.50 yr
Average life ratio:	pickups/sedans	1.97	1.70

APPENDIX 3.
COST OF ALUMINIZED PARTS VERSUS STEEL PARTS ON 1949 THROUGH 1952 CHEVROLET SEDANS

	Replacement Cost[a]	Average Life (years)	Annual Cost	% Saved by Using Aluminized Parts
Steel Muffler	$5.73	1.27[b]	$4.51	-
Aluminized muffler	6.13	2.16(est.)[c]	2.84	37
Steel tailpipe	3.57	0.880[b]	4.06	-
Aluminized tailpipe	3.82	1.10[d]	3.47	14.5

(a) Appendix 4
(b) Appendix 2
(c) Appendix 5
(d) Appendix 1

APPENDIX 4.
COST DATA

The costs itemized below are based on current average costs of labor and material at the Construction Battalion Center, Port Hueneme, California. Labor costs include 10% for overhead. Muffler and tailpipe costs pertain to 1949 through 1952 Chevrolet passenger vehicles.

Replacement cost using steel muffler:

Labor, 0.9 hr x $2.59/hr	:	$2.33
Muffler[a]	:	3.40
Total		$5.73

Replacement cost using aluminized muffler:

Labor, 0.9 hr x $2.59/hr	:	$2.33
Muffler[b]	:	3.80
Total		$6.13

Replacement cost using steel tailpipe:

Labor, 0.7 hr x $2.59/hr	:	$1.82
Tailpipe[c]	:	1.75
Total		$3.57

Replacement cost using aluminized tailpipe:

Labor, 0.7 hr x $2.59/hr	:	$1.82
Tailpipe[d]		2.00
Total		$3.82

(a) BUDOCKS repair parts stock no. YF 78-350-3698040
(b) BUDOCKS repair parts stock no. YF 78-350-3698038
(c) BUDOCKS repair parts stock no. YF 78-350-3697600
(d) BUDOCKS repair parts stock no. YF 78-350-3698043

APPENDIX 5.
DETERMINATION OF LIFE EXPECTANCY OF ALUMINIZED MUFFLER C WHEN INSTALLED ON 1949 THROUGH 1952 CHEVROLET SEDANS

This calculation is based on the assumption that the life expectancy of a muffler varies inversely as its loss of weight caused by corrosion. This assumption, though not strictly correct, is conservative since the corrosion rate is expected to decrease with time; the accrued scale tends to act as a shield against further corrosion.

Let q = annual weight loss of aluminized muffler on pickup.
x = annual weight loss of aluminized muffler on sedan.
x' = life expectancy of aluminized muffler on sedan.
y = annual weight loss of steel muffler on sedan.
y' = life expectancy of steel muffler on sedan.
z = annual weight loss of steel muffler on pickup.
z' = life expectancy of steel muffler on pickup.
k_x = constant of proportionality (weight loss of aluminized muffler on sedan at failure)
k_y = constant of proportionality (weight loss of steel muffler on sedan at failure)
k_z = constant of proportionality (weight loss of steel muffler on pickup at failure)

x' varies as $1/x$ according to basic assumption

Similarly y' varies as $1/y$

and z' varies as $1/z$

Then $x'x = k_x$, $y'y = k_y$, $z'z = k_z$

But $k_x = k_y = k_z$ approximately

Therefore $x'x = y'y = z'z$ or $z'/y' = y/z$ and $x'/y' = y/x$

But $x/q = y/z$

Therefore $x/q = z'/y'$

$z'/y' = 1.97$ from Appendix 2

Then $x/q = 1.97$

Also $y/q = 0.609/0.182 = 3.35$ from Appendix 1

Therefore $y/x = 3.35/1.97 = 1.70$

But since $y/x = x'/y'$

Then $x'/y' = 1.70$

And since $y' = 1.27$ years

Then $x' = (1.70)(1.27) = 2.16$ years

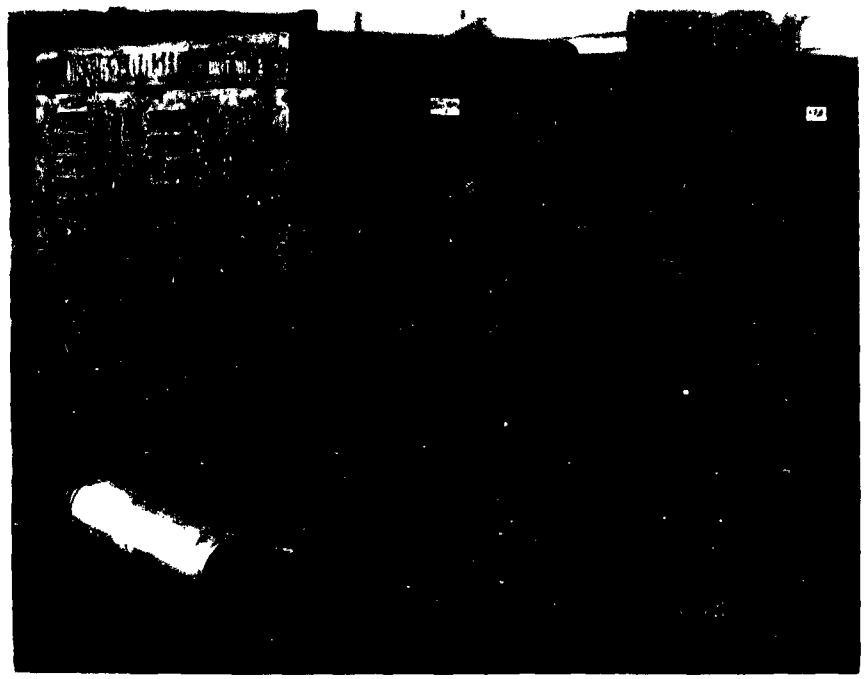

Figure 1. Aluminized muffler A (left) and steel muffler B 7 months after installation on Chrysler industrial gasoline engines.

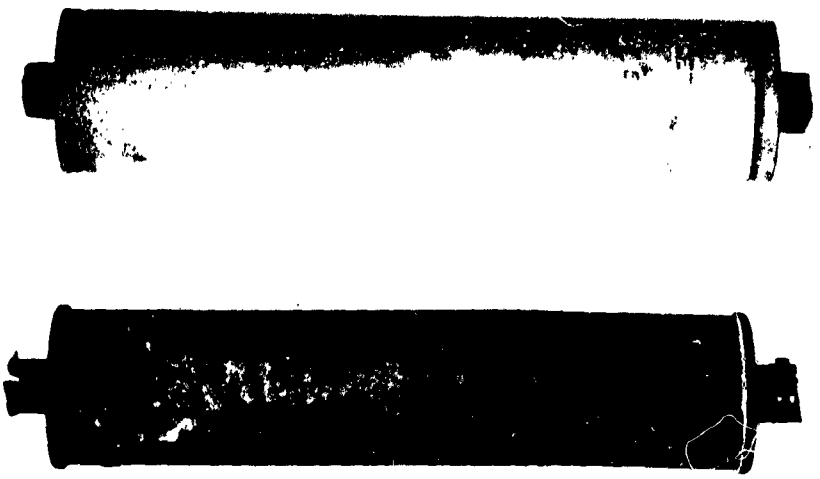

Figure 2. Aluminized muffler A (top) and steel muffler B after 746 hours of operation.

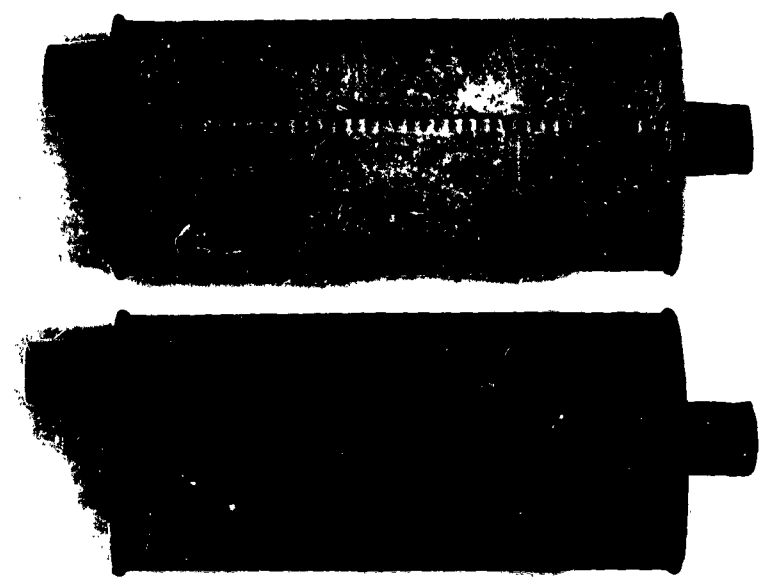

Figure 3. Aluminized muffler C (top) and steel muffler D after approximately 2 years of service.

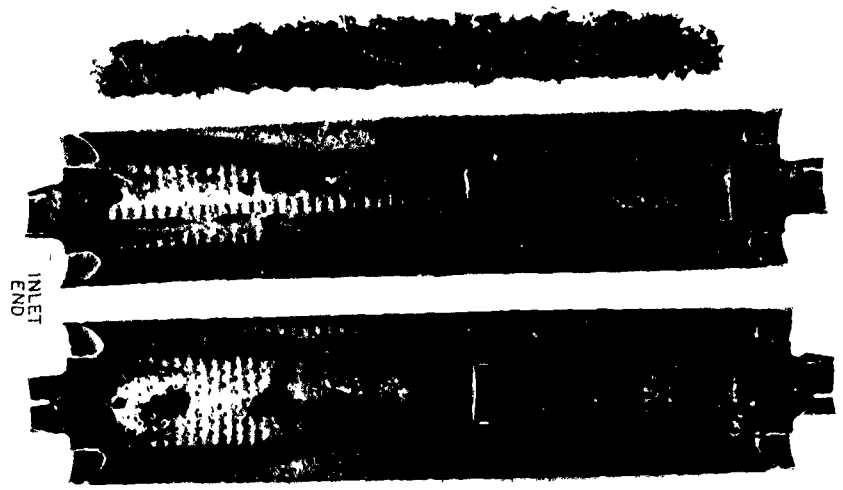

Figure 4. Aluminized muffler A bisected, showing internal scale before pickling.

Figure 5. Steel muffler B bisected, showing internal scale before pickling.

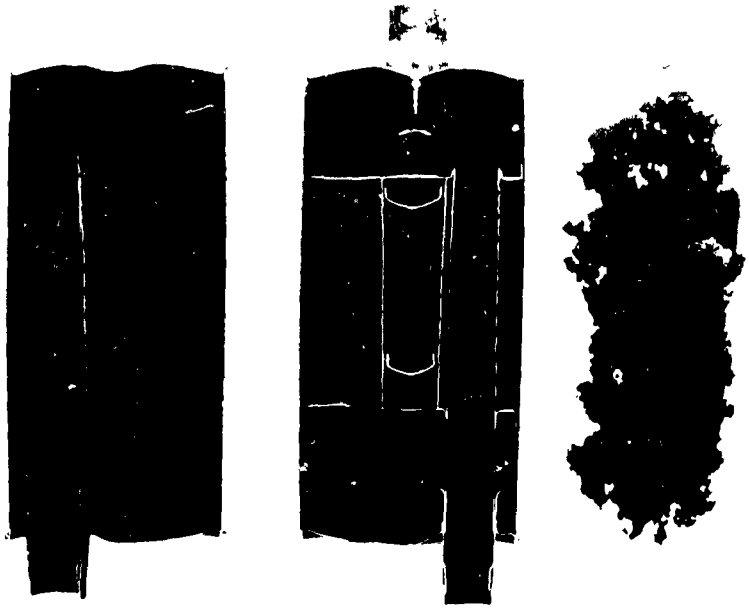

Figure 6. Aluminized muffler C bisected, showing internal scale before pickling.

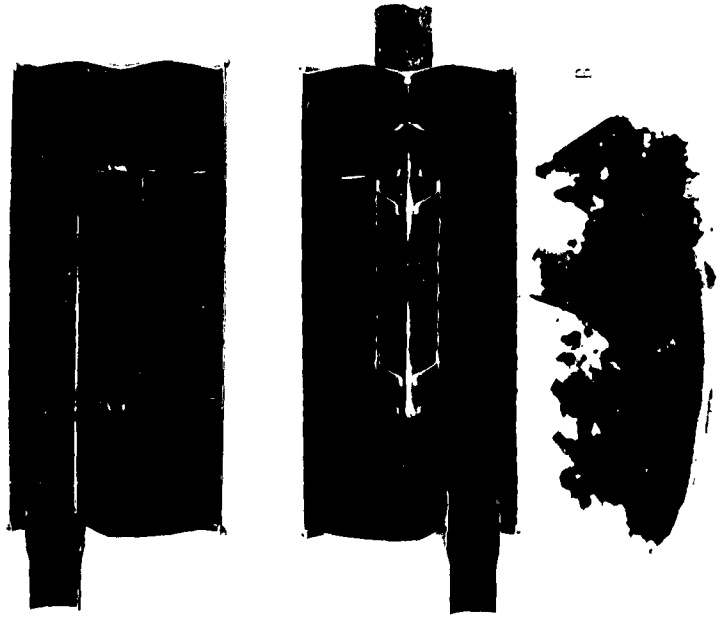

Figure 7. Steel muffler D bisected, showing internal scale before pickling.

Figure 8. End of aluminized tailpipe A after one year of service. Rust on the end and one hole on bottom of tailpipe forward of bracket were the only exterior corrosion visible at this time.

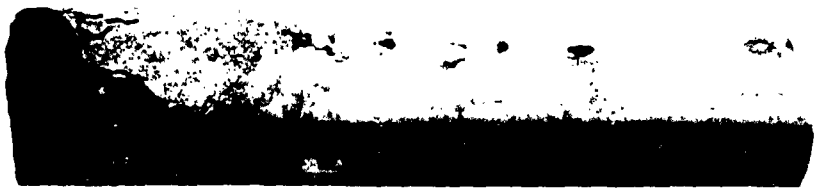

Figure 9. Last 8" of aluminized tailpipe A showing holes along the bottom at the conclusion of 13 months of testing.

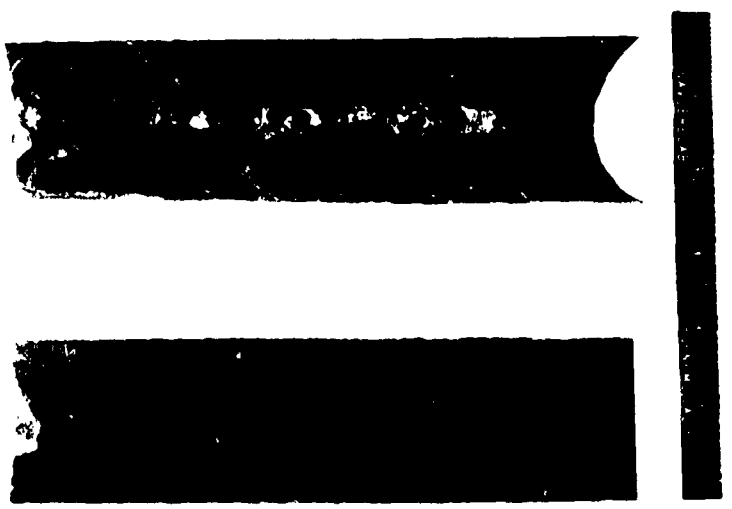

Figure 10. Last 8 inches of aluminized tailpipe A bisected, showing internal corrosion. Bottom of tailpipe is shown at top of picture.